

Do-it-yourself

Bat Detector

manual

FRANZIS

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Build your own bat detector

In warm summer nights bats hunt for insects – in many places and largely unnoticed. Often we do not realise they are here because at dusk a bat can easily be mistaken for a small bird. But most bats come out when the birds are already roosting. In this way they avoid being attacked by birds of prey. When you're in your garden, on the balcony or out in the wild on a summer evening, just watch and see what is fluttering around. Eventually, all birds have found their roost. You still hear them for a while, but you do not see them anymore. What is still fluttering now might be a bat! Once you have developed a good sense for bats you will see them in unexpected places, even in the city or close to your home.

When you are looking for these interesting animals the bat detector may be helpful. In flight the animals emit ultrasonic sounds that they use for navigation and to track down their prey. We cannot hear the calls of bats. A young person can perceive sounds up to a frequency of 20 kHz, with older age this threshold decreases, sometimes below 10 kHz. Bats call at frequencies far above 20 kHz, depending on species they may, for

instance, call at 40 kHz or still higher frequencies. The bat detector translates such high frequencies into deeper sounds that we are able to hear clearly. And that's why you will hear the bats more often with this device than you will see them. With some practice you will hear that a bat is around. You can even find the bat's direction with the device. And then it will be no longer difficult to see the animals at dusk.

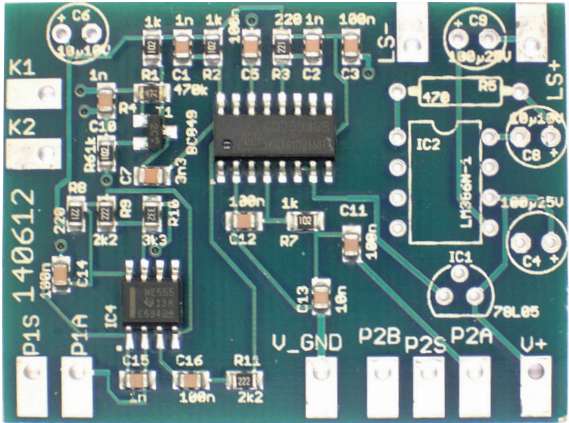
Now have fun with assembling your detector and observing nature!

Components

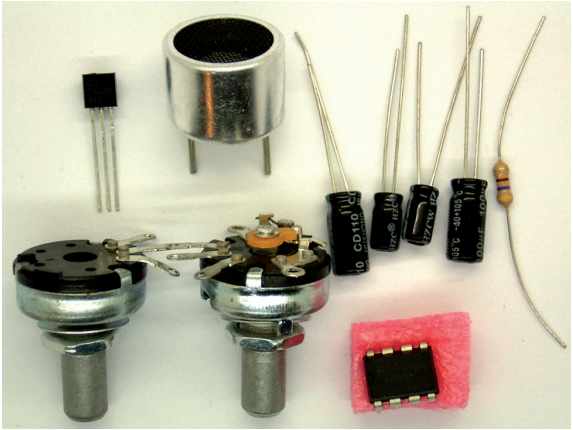
The core of the kit is an SMD circuit board equipped with the most important components. SMD stands for Surface-mount device. The components are so tiny that it would be very difficult for you to solder them on yourself. Thus the job was handled for you by a pick-and-place robot. You will only have to solder on a few components with connecting wires.

The other main components are the ultrasound microphone, the speaker and the two controllers for volume (with switch) and frequency. The remaining components must still be soldered on the PCB. The IC amplifier LM386 with eight connec-

tor pins provides the necessary volume. The voltage regulator 87L05 with three connector pins looks like a customary transistor and ensures a stable voltage of 5 V in the circuit. In addition, there is a resistor with rings coloured yellow, violet, brown and gold, with 470Ω and an accuracy of 5%. Finally, there are four electrolytic capacitors, two of them with $10 \mu\text{F}$ (microfarad) and two with $100 \mu\text{F}$.



The PCB



Components

- equipped circuit board
- speaker 8 Ω
- ultrasound microphone 40 kHz
- potentiometer 22 k Ω with switch
- potentiometer 22 k Ω
- two rotary buttons
- IC1 78L05; IC2 LM386
- R5 470 Ω (yellow, violet, brown)
- C6, C8 electrolytic capacitor 10 μ F

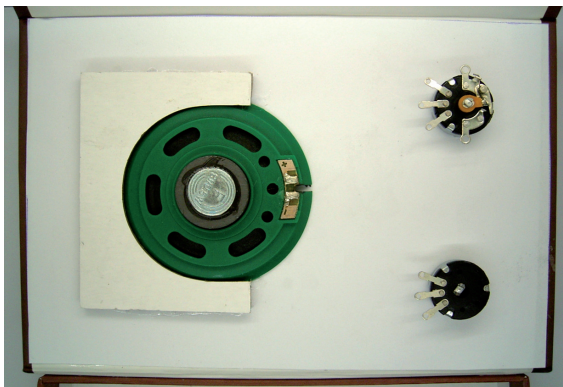
- C4, C9 electrolytic capacitor 100 μ F
- wire strands, 9-volt battery clip

Assembly of the control elements

The finished device has two rotary controls – one for frequency (kHz) and one for volume (Vol), and a speaker behind the sound holes. Open the housing by pulling up the cover's side flap with its magnetic catch. The components are then assembled from the inside. To accomplish this, you do not yet need a soldering iron. But flat-nose pliers and some adhesive may be helpful.

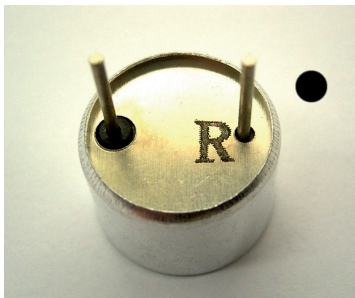


First build in the speaker by sliding it into the corresponding holder. Ideally, apply some adhesive to fix it permanently. Install the two potentiometers as shown in the image. The potentiometer with the additional rotary switch and the total of five terminals is the volume controller (Vol), the potentiometer with only three terminals is the frequency regulator (kHz). A small tab ensures correct insertion. Screw both potentiometers with the ring nuts tight and do not forget the corresponding washers. When tightening the nuts flat-nose pliers may be helpful.



Speakers and potentiometers

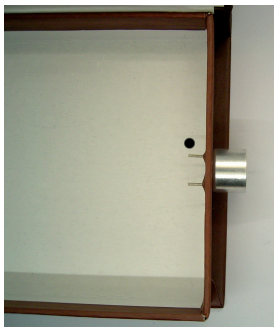
When installing the ultrasound microphone you have to observe the mounting direction. One of the two terminals (ground, right side in the photo and marked with a black dot) is electrically connected to the aluminium housing, the other one (signal, left side in the photo) is insulated against the housing.



The microphone

Install the microphone in the upper side wall of the housing in such a way that the ground pin is closer to the hinged cover. You may also mark this terminal with a dot as in the photo so that it will not be confounded later. The microphone should be attached with some adhesive to avoid movement and background noise. For this reason it will later be more difficult to determine which one is the ground terminal on the microphone housing. However, if the two microphone terminals are confounded after

all, the device will still work though it will be a little more sensitive to interfering signals. You can correct this easily by exchanging the connecting wires.



Assembly of the microphone

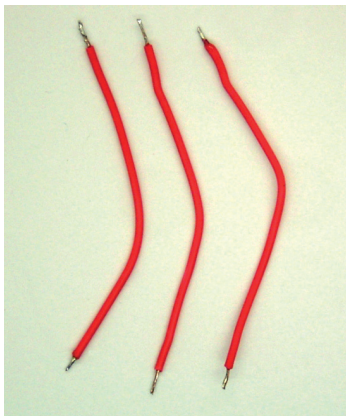
Soldering

If you have scarce experience with soldering, it will be a good idea to begin with the wires and prepare them using the soldering iron. You need five cable sections to assemble your detector. First, cut off cable pieces of the following length:

2 x 12 cm

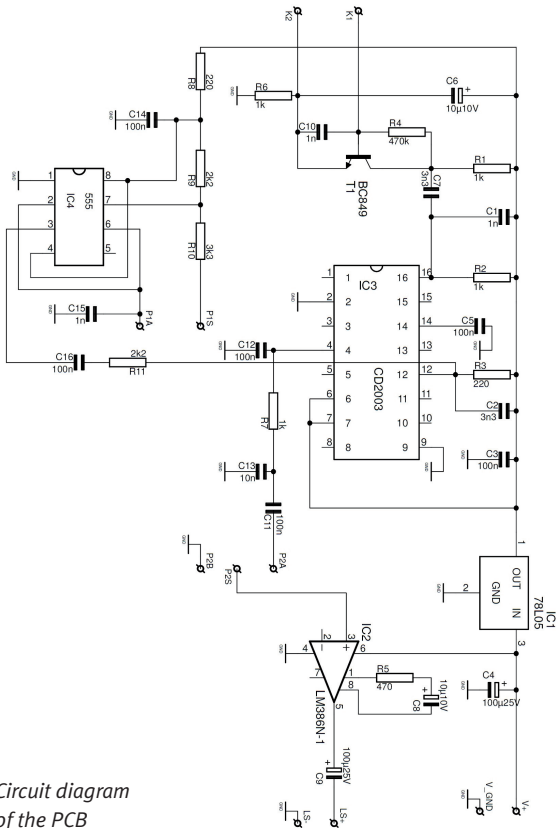
3 x 5 cm

Remove 5 mm of the insulation from the cable ends. The insulation is relatively soft and can be stripped off with the fingernails using some strength. Twist the fine wires with your fingers. Tin the stripped cable ends with the soldering iron to keep the fine wires together. Be sure to touch the cable end simultaneously with the soldering iron and the tin solder.



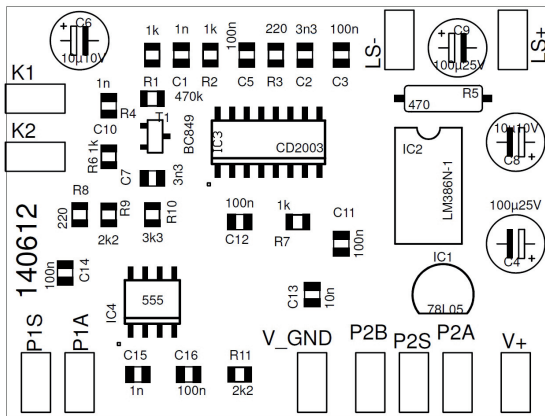
Tin-plated cables

Now solder the remaining wired components on the PCB. Some components have very long wires that have to be pinched off after soldering. Keep these wires as you will still need them when you connect the potentiometers and the speaker.



Circuit diagram of the PCB

The circuit diagram of the PCB is for orientation, refer to it if you already have experience with electronic circuits. However, the device will work properly even if you do not understand every detail accurately. At the end of these instructions you will additionally find the complete circuit diagram including microphone, speaker and potentiometers.

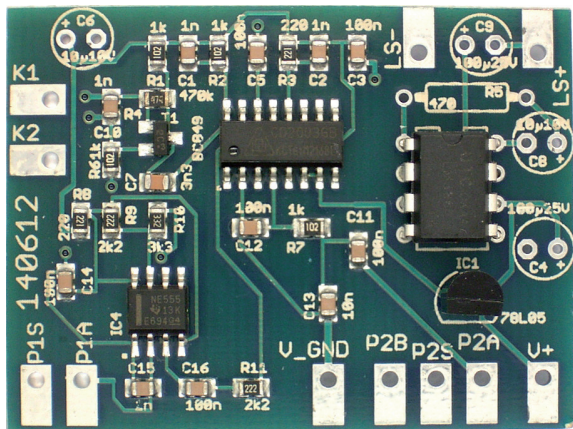


Layout diagram of the circuit board

The layout diagram shows all components with their respective values and part numbers. First, compare the PCB with the layout diagram to get an overview of the components and to

understand which ones are already soldered on and which ones you have to install yourself.

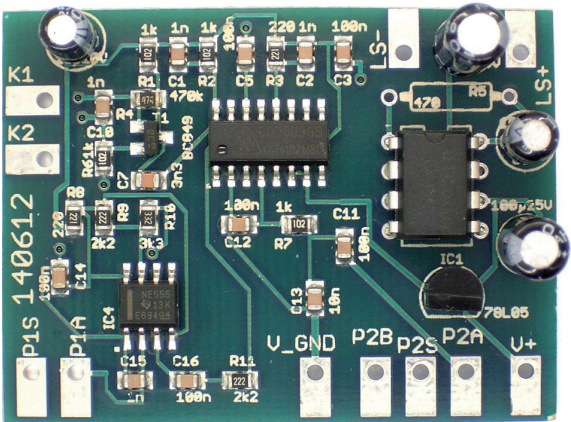
First install the integrated circuits. Begin with the speaker amplifier LM385 (IC2). The connector pins are not completely parallel to each other when they come from the factory and have to be aligned. To achieve this, press the IC laterally on a table so that the pins of one side are all bent slightly inwards. Then you can easily insert it in the PCB. Be sure to observe the mounting direction. The PCB print shows a notch that you will



IC1 and IC2 installed

also find on the IC. Then solder on each pin at the bottom side. The lands are relatively small and surrounded by a large ground pad. But the solder resist prevents the liquid solder from leaving the area of the actual solder joint. Solder in the voltage regulator 78L05 (IC1). Due to the triangular connector configuration and the PCB print an improper mounting direction is excluded.

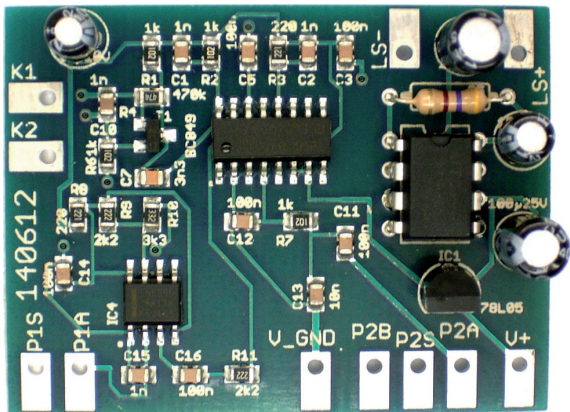
Next build in the electrolytic capacitors. Observe the mounting direction. The electrolytic capacitors have a white line indicating their negative pole. The opposite positive pole is marked with a



Electrolytic capacitors installed

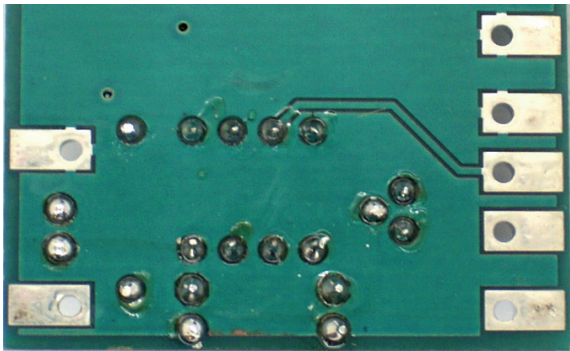
plus sign on the PCB. Before soldering, please check the direction once again. The white line on the two upper electrolytic capacitors – C6 (10 μ F) and C9 (100 μ F) – points towards the right, the white line on the two capacitors on the right side – C4 (100 μ F) and C8 (10 μ F) – points towards the left. Pinch off the long wires only after soldering and keep them for final assembly.

Now there is only one remaining component, the resistor with 470 Ω (yellow, violet, brown). This time the mounting direction is not important.



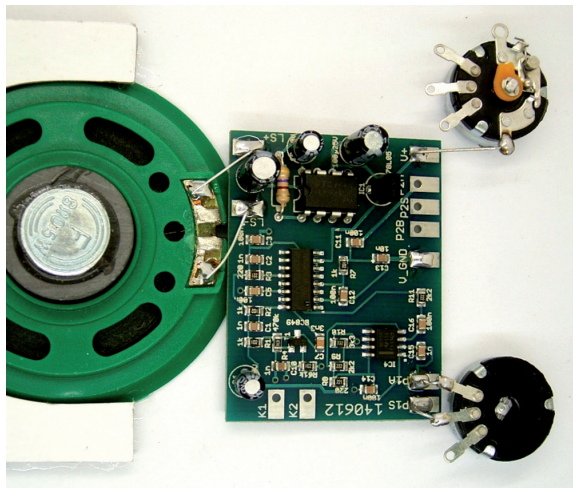
The fully equipped PCB

Finally, check the solder joints. You can tell a reliable connection by its smooth surface. Usually there is some soldering flux to be found beside the soldering joints. This is completely harmless as it is a good insulator.



Soldering joints on the PCB's bottom side

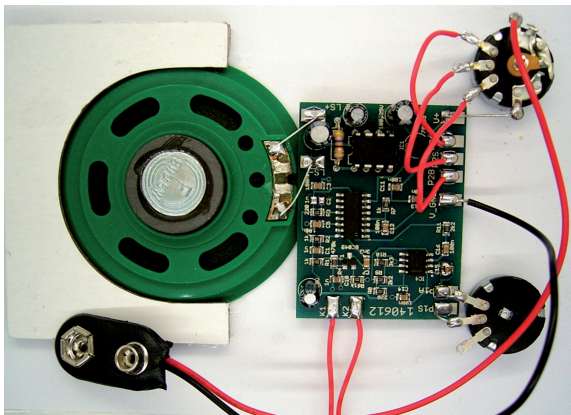
For the final assembly, the PCB is connected to the remaining components so that it is also mechanically secured. Use the cut hard wire pieces of the electrolytic capacitors for some of the connections so that the board is held in a stable position.



Installing the hard wires

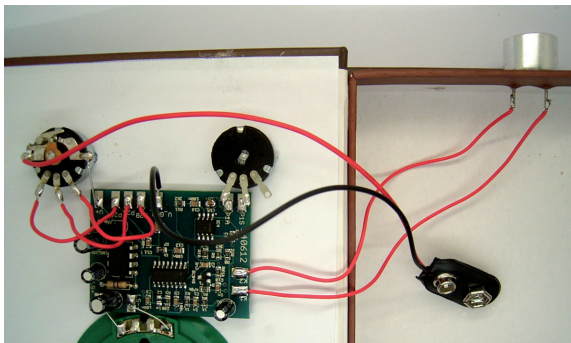
The terminals LS+ and LS- are connected with the speaker using short wire pieces. One wire leads from V+ to a pole of the switch on the volume potentiometer. The P1A terminal is connected with the upper terminal of the frequency potentiometer, the P1S terminal leads to the middle pin (slider). Now the PCB is held on three corners with five hard wire pieces and is thus firmly mounted.

The remaining connections are built using soft wires. The three terminals P2B, P2S and P2A lead to the volume potentiometer. The positive pole (red) of the battery clip is soldered on the second pole of the switch. The negative pole leads to the GND terminal (ground).



Installing the soft wires

Two more wires, each 12 cm long, lead to the ultrasound microphone. K2 is connected to the ground terminal of the microphone, K1 to the signal terminal. The two cables will not cross each other.



Connection to the microphone

Initial test

Insert a 9-volt battery and switch on the device. First set it to a medium volume. You will hear a low noise. Rub the pads of your index finger and thumb lightly together. It will make a soft sound that you will only perceive close to your ear. There is an ultrasonic part contained in this sound so it is suited as a test for the ultrasonic detector. The device will convert these ultrasonic sounds into audible sound. Do the testing for different frequencies. If the regulator is set to a medium position, the sounds will be particularly loud. You find the optimal position

at about 40 kHz. The ultrasonic detector will be most sensitive at this frequency. The sounds of rubbing fingers can be heard clearly from a distance of one metre.

Test the device at different settings and also at full volume. If everything is fine, the device works reliably. If you hear a whistling sound that disappears at lower volume, an acoustic or electric feedback has occurred. It may be caused by a low battery. Another possible cause is that the microphone is not attached properly. In this case make sure that the ultrasonic microphone is firmly attached to the housing so it cannot move and that sound cannot escape from there to the outside.

If something does not work the way it should, then check every soldering joint using a magnifier. Look for discontinuities and wrong connections due to solder splashes or the like. If you have a measuring instrument at hand, you can check the operating voltage of 9V and also the stabilized voltage of 5V.

Use a small piece of bare wire for further testing by touching different terminals. To test the power amplifier, touch either the P2S terminal or pin 2 of the LM386. You should hear a light buzzing sound from the speaker. Touch the terminals P1A or P1S. This will result in a loud cracking and a modified noise if everything is fine around the NE555 oscillator. To test the preamplifier and the mixer touch the microphone input at the K1 pin. This should generate a loud noise or humming sound

because interfering electric signals are being coupled in just like via an antenna. You should also tap the microphone connections and the microphone housing. Only the signal pin should make a loud sound. If this effect also occurs when touching the microphone housing, the microphone is not properly connected. In this case, reverse the connecting wires.

Observing bats

Bats can be watched only during the summer months. In winter, they hibernate in caves or abandoned buildings where they should not be disturbed. But during the breeding season in the warm months you find them almost everywhere, even in the city. Some widespread species, e.g. the pipistrelle, can live within the smallest hollows which can be found even in modern buildings, or they roost in tree hollows. During the day they remain virtually invisible. But in the evening they flutter around searching for insects.

When you already know that there are bats around your home, you only need to wait until dusk. Switch on your detector and set it at a medium frequency of 40 kHz. Make a sound with your fingers to tune into the most sensitive frequency. Then hold the microphone into various directions. Just like with a searchlight you can scan your whole surrounding that way. Eventually, you will hear the particular sounds of a bat. And once you have

found the right direction seeing them will no longer be difficult. Usually they fly in narrow circles hunting for insects. Sometimes they persistently chase around a tree or again and again along a house, sometimes they navigate close above the ground, depending on where most insects happen to be.

When bats fly close enough towards the observer, the sounds become clearly louder. The sounds are emitted in forward direction so that the echo will reveal obstacles and possible preys. Look for the optimum frequency. If it is set properly you will be able to hear that, for instance, the pipistrelle does not call at a constant frequency but modulates pitch while calling. With the aid of your bat detector you will hear some sort of chirping. So every species has a distinct type of sound. Experienced wildlife observers recognize the species based on their calls.

Some locations provide ideal living conditions for bats. A typical example is a small forest lake. The water body attracts midges, dragonflies and other insects in unbelievable numbers. At the same time the surrounding trees provide sufficient hideouts and roosts for the bats. You should give it a try out there! Just wait until dusk when the birds are not flying around anymore. Switch on your detector and search in all directions. Eventually, you will hear the typical sounds of bats. Often it is quite difficult to see them. The bat detector helps you to determine the direction. Perhaps you have been looking at the water all the time, hoping to spot the animals close to the surface, but the device is point-

ing upwards. And sure enough, there is a larger swarm between the tree tops, well visible against the evening sky. In other cases the detector will point forward and you discover the animals low above the water. But it may also happen that two species are around at the same time, e.g. Daubenton's bats and pipistrelles. Try then to distinguish the two on the basis of their sounds and their preferred frequencies.

Many cities offer guided bat-watching tours. Draw on the experience of experts who can tell you more about the bats in your neighbourhood. Which species are living here, how can they be recognised, where are the cavities where they roost, and what can be done to preserve their habitats? In this way you will develop a good sense for these animals and will discover them where you have not seen them before.

Ultrasound experiments

To become more familiar with the device and how it is operated you should examine as many ultrasound sources as possible. Just rattle with a key ring in front of the microphone. That will generate sounds resembling bells. Metal objects being hit will echo in the ultrasonic range. This holds also true for screws and nails. Some objects have a clear natural frequency than can be heard very well when the device is adjusted to a particular fre-

quency. Clicking the buttons of your computer mouse will also produce sounds in the ultrasonic range because the involved metal parts are very tiny.

Other sounds often appear very soft in the normal audible range but very loud in the ultrasonic range. That applies, e.g., to bursting gas bubbles in a glass of sparkling water or champagne and to dropping grains of sand or gravel. Also all sorts of rubbing noises, for instance the scratching of a fingernail on a sheet of paper, will be clearly audible.

If you walk around in your rooms with the device you will be amazed at the number of places where ultrasound is radiated. For instance, energy saving lamps are strong ultrasonic sources. The built-in coil of the electronic ballast usually generates ultrasound within the 30 to 50 kHz range. The noise is often modulated by a buzzing that equals the supply frequency.

Many other mains-operated devices contain switching power supplies with frequencies in the reception range of the ultrasound detector. For the most part, built-in coils or transformers generate ultrasonic sounds which are made audible with the device. When tuning across the range you will hear a deep sound at one point on the scale which will get higher in both directions. This beat tone equals the difference frequency of the signal frequency and the set oscillator frequency.

Binaural beats

Particularly stable ultrasonic sounds are radiated by tube monitors and TVs. You can hear their line frequency or overtones. A traditional tube TV uses 15.625 kHz, while a high-resolution PC monitor, e.g., operates at approximately 60 kHz. Using the frequency regulator you can adjust a well audible tone of, e.g., 1 kHz. The tone is the difference of input frequency and oscillator frequency and is also called beat tone or binaural tone.

Set the oscillator frequency exactly at the receiving frequency. Now only a very deep tone or no tone at all will be generated because the difference frequency is zero. This setting is called zero beat.

You can observe another type of beat when two sound sources with almost identical frequencies are heard. Then the tone appears to rise and fall with the pulse of the difference frequency, i.e. the intensity is changing all the time. You can observe this effect, for instance, when there are two energy saving lamps of the same type being operated simultaneously.

The Doppler effect

The Doppler effect is the change of pitch (frequency) due to the relative motion of the source and the receiver of a particular sound. The effect is known from rapidly passing vehicles. The engine noise, a horn or a siren seems to get higher as it approaches and lower as it departs.

The Doppler effect becomes even more pronounced with the ultrasound detector. It can be heard well at lower velocities due to the fact that a relative frequency change will increase by downmixing. A pitch change by 1% at 40 kHz accounts for 400 Hz. When mixed down to 1 kHz there is still the same difference of 400 Hz, but now it accounts for 40% and can thus be heard more clearly.

Set the frequency regulator at approximately 1 kHz below zero beat, so that you hear a clear sound. Then move the ultrasound detector towards the source of the sound. The pitch gets higher. Move it away from the source of the sound, and the pitch gets lower. The audio frequency is modulated by a swift back-and-forth movement.

Standing waves and wavelength

Any sonic wave is reflected by walls and objects. This also holds true for ultrasound, and bats utilise it to locate obstacles. When sound is reflected, there are places where the incident wave and the reflected wave superimpose each other. At some points this leads to an amplification of the sound, at other points the sound will be reduced or even disappear. Then you find standing waves with loud and quiet places. You can intimately study such a sound field with your ultrasound detector. Scan the room to find places where an ultrasonic signal is just disappearing.

When standing waves occur you can easily measure wave length. This is best done when the sound is reflected from a straight wall back to the exact position of its source. The shortest distance between two volume minima is one half wavelength.

You can calculate the frequency from the wavelength, according to the following formula: $\text{frequency} = \text{sound velocity} / \text{wavelength}$. Sound velocity is about 330 m/s. If you measure a wavelength of one centimetre, the frequency is 33 kHz. Conversely, you can calculate the wavelength of 8.25 mm from a frequency of 40 kHz. Generally it holds: the higher the frequency, the shorter the wavelength. This rule is essential for bats because reflections only allow the detection of details in the order of the wavelength or bigger. Smaller bat species hunt for tinier insects and therefore must emit sounds at a higher frequency.

Electrical signals

The ultrasound detector is electrically not shielded and thus will receive not only sound signals but also electrical signals in the same frequency range if the electric field strength is high enough. In front of a tube monitor you will perhaps receive a sound signal and simultaneously an electrical signal at the deflection frequency. They can be unambiguously distinguished on the basis of the Doppler effect that can be observed only for sound signals. Basically the Doppler effect does also hold true for electrical waves, however, speed would have to be a million times higher. So if you are not sure whether you are receiving a sonic or an electrical signal, just move the detector back and forth. If the audible frequency then changes, it is clearly a sound signal.

At little expense, the ultrasound detector can be enhanced to serve as a detector for alternating fields in the frequency range from 20 kHz to 100 kHz. Solder an additional wire 10 cm in length on the K1 microphone input. This wire shall then stick out of the housing as an antenna. Use it to check, e.g., the surroundings of electrical devices. You will detect numerous signals. LCD flat screens indicate, for instance, different noises at different spots before the display. At some frequencies you will even hear sounds that change along with the picture content.

Check also other devices like power supplies, lamps, clocks or engines. Every device has a sound of its own and its distinct

frequency. Cables and lines can also be traced, sometimes even when they are laid under masonry or plaster. One of the strongest electromagnetic sources are thunderstorms. Lightning flashes emit signals mainly in the frequency range below 100 kHz. Therefore you can also use your bat detector as a thunderstorm warning device.

Explanations on the wiring diagram

The most essential components of the bat detector come from radio technology. The task is quite similar: High frequency signals have to be processed so that they become audible. But instead of an antenna the bat detector has a special microphone with its highest sensibility in the ultrasonic range at approximately 40 kHz. The signals are transmitted to a mixer which converts them to lower frequencies. Just like you can tune your radio to particular frequencies, you can tune your ultrasound detector within a range from 20 kHz to 100 kHz. This will help you to hear and distinguish different species of bats. Moreover, it can help you to discover and examine many other ultrasound sources.

The device works as a direct mixer that blends the input signal and the oscillator frequency; the result then falls within the audible range. If, for instance, you set an oscillator frequency of 39 kHz, an input signal of 40 kHz will be mixed down to the differ-

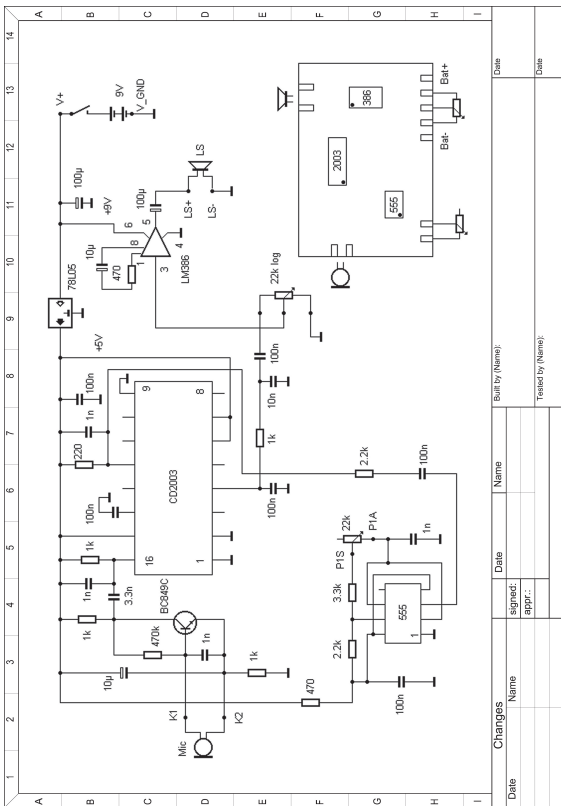
ence frequency of 1 kHz. The same input signal will also be audible at 1 kHz when the oscillator frequency is 41 kHz. Crucial factors for the quality of the device are high amplification, low noise and a good suppression of a possible acoustic feedback, which might cause a whistling noise. The ultrasound microphone being used has a pronounced resonance at 40 kHz and only a low sensitivity to frequencies in the lower audible range. But altogether signals between 20 kHz and 100 kHz can be processed.

The ultrasound microphone is directly connected to the basis of the low-noise transistor BC859. This preamplifier offers an optimum adaptation and a voltage gain of 100 (20 dB). A parallel capacitor in the input suppresses penetrating HF signals and reduces sensitivity with respect to electromagnetic interference. The coupling capacitor between preamp and mixer IC CD2003 is so tiny that only high frequencies are transmitted unsuppressed. This high pass filter reduces the danger of acoustic feedback.

The central IC CD2003 was originally developed for radio receivers. It is the core of an AM/FM radio with oscillators, mixer stages, intermediate frequency amplifiers and demodulators for the two ranges. Here only the AM preamplifier and the AM mixer stage are used. The radio IC offers a total amplification of 40 dB and a suppression of the input signal of -20 dB. The output of the mixer provides a low pass filter for an additional damping of the input signal.

The audio amplifier LM386 receives the full operating voltage of 9V and delivers an output power of up to 500 mW to the 8 Ω speaker. The amplification is set with the 470 Ω resistor at pin 1. You can omit the resistor in order to reduce the amplification by approximately 10 dB. Alternatively, you can also install a wire jumper instead of the resistor to increase the amplification by 10 dB. The higher the amplification, however, the sooner acoustic feedback with unpleasant whistling noises will occur.

The power amplifier usually causes certain voltage dips on the operating voltage because the internal resistance of the battery cannot be made indefinitely low. A parallel electrolytic capacitor with 100 μ F supports the supply voltage and enables stable operation, even if the battery is not fully charged any more. For the pre-amplifiers the requirements in regard to power supply are much higher. Therefore a 78L05 voltage regulator was installed which provides a stable 5V voltage.



Changes		Name		Date	
Date		signed:		Built by (Name):	Date
		appr.:			
				Tested by (Name):	Date

